ANYALISIS OF MAGNETOELASTIC SENSORS

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Introduction

The magnetoelastic sensor is a novel sensing platform, currently being used in anti theft tags and it has a potential to be used in environmental sensing. The objective of this project was to study the characteristic of a magnetoelastic resonator as a function of varying power and lengths. The basic principle is that when it is struck with a magnetic flux that results in the sensor resonating at a particular frequency that can be detected using coils.

What are magnetoelastic sensors?

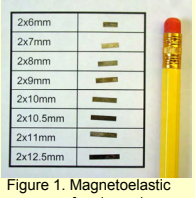


Figure 1. Magnetoelastic sensors of various sizes.

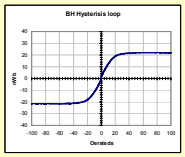


Figure 2. BH hysteris loop of One of the sensors

Small strips made of amorphous alloy also known as Metallic Glass are used as magnetoelastic sensors. It is manufactured such that it has only microscopic crystal structure giving a minimal hysteresis loop as shown in Fig.2

- Rectangular shape provides good acoustic resonance
- Magnetostrictive property implies no physical connections (such as wires)
- Similar principles to a surface acoustic wave device (Quartz crystal)

What is magnetostriction?

It is defined as the strain induced on an object by change in magnetization. For our material strain is in the direction of the applied magnetization. Magnetostriction may be derived by

$$e = \frac{3}{2}\lambda_s\left[\left(\frac{M_f}{M_s}\right)^2 - \left(\frac{M_i}{M_s}\right)^2\right]$$

e: Strain
λ_s : Magnetostriction constant
M_f : Final State of Magnetization
M_i : Initial State of Magnetization
M_s : Saturated State of Magnetization

If you apply $H=e^{j\omega t}$ you get strain $e = e^{j\omega 2t}$
But if we apply $H_{DC}+e^{j\omega t}$
Initial Mi now becomes M_{dc}
And Final Mf = $M_{dc} + M_{ac}$
Substituting in previous equation

$$e = \frac{3\lambda_s}{2M_s^2}\left[M^2_{dc} + 2M_{dc}M_{ac} + M^2_{ac} - M^2_{dc}\right]$$

$$e = \frac{3\lambda_s}{2M_s^2}\left[2M_{dc}M_{ac} + M^2_{ac}\right]$$

Small signal approximation $M_{ac} << M_{dc}$

$$e = \left(\frac{3\lambda_s M_{dc}}{M_s^2}\right)M_{ac} = dM_{ac}$$

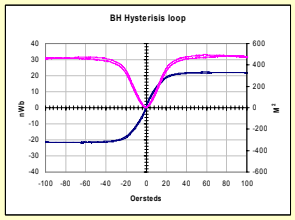


Figure 3. BH hysteris loop(blue) and strain (purple) of One of the sensors

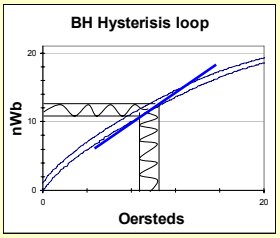


Figure 4. Small signal approximation Made on a BH hysteris loop

ΔE Effect

The sensors resonate at a frequency which depends on modulus of elasticity E, length of sensor and density of material

$$f_r = \frac{1}{2L}\sqrt{\frac{E}{\rho}}$$

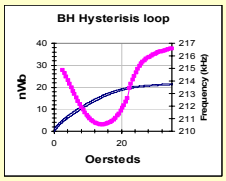


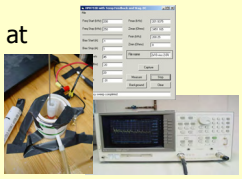
Figure 4. BH hysteris loop and a Frequency sweep showing ΔE effect

E depends on applied field hence frequency also depends on it, this is known asΔ E effect.

Measuring Method and Setup

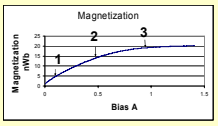
Measuring impedance of a solenoid with the sensor inside. The equation at steady state is given by

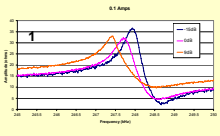
$$Z = j\omega A\left(\frac{N}{l}\right)\chi\left[\frac{\omega^2{}_m - \omega^2 + j\omega C}{\omega^2{}_H - \omega^2 + j\omega C}\right]$$

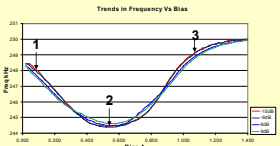


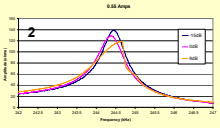
A combination of coils with an Impedance analyzer along a with a computer is used to perform experiments.

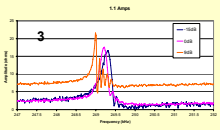
Results & Summary

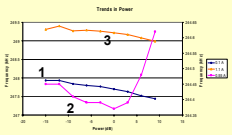












Individual points on the applied field were observed and resulted in the following conclusions

- Distortion occurs and increases as power level is increased
- The observed trend in resonant frequency vs. power depends on the bias condition